Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission

Updated Oct. 5, 2020

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory droplets carrying infectious virus.

Respiratory droplets are produced during exhalation (e.g., breathing, speaking, singing, coughing, sneezing) and span a wide spectrum of sizes that may be divided into two basic categories based on how long they can remain suspended in the air:

- **Larger droplets** some of which are visible and that fall out of the air rapidly within seconds to minutes while close to the source.
- **Smaller droplets and particles** (formed when small droplets dry very quickly in the airstream) that can remain suspended for many minutes to hours and travel far from the source on air currents.

Once respiratory droplets are exhaled and as they move outward from the source, their concentration decreases through fallout from the air (largest droplets first, smaller later) combined with dilution of the remaining smaller droplets and particles into the growing volume of air they encounter.

Respiratory viruses are transmitted in multiple ways

Infections with respiratory viruses are principally transmitted through three modes: contact, droplet, and airborne.

- **Contact transmission** is infection spread through direct contact with an infectious person (e.g., touching during a handshake) or with an article or surface that has become contaminated. The latter is sometimes referred to as "fomite transmission."
- **Droplet transmission** is infection spread through exposure to virus-containing respiratory droplets (i.e., larger and smaller droplets and particles) exhaled by an infectious person. Transmission is most likely to occur when someone is close to the infectious person, generally within about 6 feet.
- **Airborne transmission** is infection spread through exposure to those virus-containing respiratory droplets comprised of smaller droplets and particles that can remain suspended in the air over long distances (usually greater than 6 feet) and time (typically hours).

Droplet transmission consists of exposure to larger droplets, smaller droplets, and particles when a person is close to an infected person. Airborne transmission consists of exposure to smaller droplets and particles at greater distances or over longer times.

These modes of transmission are not mutually exclusive. For instance, "close contact" refers to transmission that can happen by either contact or droplet transmission while a person is within about 6 feet of an infected person.

The term "aerosol" has been used in various ways to describe small particles that can move through the air

Aerosol has been used both to define respiratory droplets of a certain size (e.g., smaller droplets and particles), as well as to describe the collection or cloud of these respiratory droplets in the air. In the healthcare setting, aerosol is used with respect to "aerosol-generating procedures" (e.g., intubation, bronchoscopy) that produce small droplets and particles and require distinct engineering controls to prevent occupational transmission of infectious pathogens like SARS-CoV-2. In community settings, aerosol was the term used to describe the sewage system-generated cloud of small droplets and particles that was believed to have spread SARS (caused by the virus SARS-CoV-1) during the 2003 Amoy Gardens outbreak in Hong Kong.

The term "airborne transmission" has a specialized meaning in public health practice

Airborne can be used to describe any size *particle* (e.g., droplet, dust, pollen) capable of travel through the air. For respiratory droplets, that can include droplets that are close to the source and those that have moved farther away. However, most infectious disease and public health experts reserve the term airborne specifically for use in the context of **airborne transmission** to describe *infections* capable of being transmitted through exposure to infectious, pathogen-containing, small droplets and particles suspended in the air over long distances and that persist in the air for long times.

Airborne transmission is not equally efficient for all respiratory microbes

For some viruses and bacteria, airborne transmission is a highly efficient mode for spreading infection. Examples include *Mycobacterium tuberculosis* (the bacterium that causes tuberculosis), rubeola (the virus that causes measles), and varicella-zoster (the virus that causes chicken pox). Although these infections can be transmitted at close range, they are also efficiently and frequently transmitted over longer distances (i.e., more than six feet) or over longer times (i.e., to people passing through an air space in which the infectious person was present minutes to hours earlier). It is especially important to control pathogens that readily infect by means of airborne transmission in healthcare and other occupational settings where special engineering controls are required to prevent spread (e.g., negative-pressure airborne infection isolation rooms, high efficiency respirators).

The epidemiology of SARS-CoV-2 indicates that most infections are spread through close contact, not airborne transmission

Diseases that are spread efficiently through airborne transmission tend to have high attack rates because they can quickly reach and infect many people in a short period of time. We know that a significant proportion of SARS-CoV-2 infections (estimated 40-45%) occur without symptoms and that infection can be spread by people showing no symptoms. Thus, were SARS-CoV-2 spread primarily through airborne transmission like measles, experts would expect to have observed considerably more rapid global spread of infection in early 2020 and higher percentages of prior infection measured by serosurveys. Available data indicate that SARS-CoV-2 has spread more like most other common respiratory viruses, primarily through respiratory droplet transmission within a short range (e.g., less than six feet). There is no evidence of efficient spread (i.e., routine, rapid spread) to people far away or who enter a space hours after an infectious person was there.

Airborne transmission of SARS-CoV-2 can occur under special circumstances

Pathogens that are mainly transmitted through close contact (i.e., contact transmission and droplet transmission) can sometimes also be spread via airborne transmission under special circumstances. There are several well-documented examples in which SARS-CoV-2 appears to have been transmitted over long distances or times. These transmission events appear uncommon and have typically involved the presence of an infectious person producing respiratory droplets for an extended time (>30 minutes to multiple hours) in an enclosed space. Enough virus was present in the space to cause infections in people who were more than 6 feet away or who passed through that space soon after the infectious person had left. Circumstances under which airborne transmission of SARS-CoV-2 appears to have occurred include:

- **Enclosed spaces** within which an infectious person either exposed susceptible people at the same time or to which susceptible people were exposed shortly after the infectious person had left the space.
- **Prolonged exposure to respiratory particles**, often generated with expiratory exertion (e.g., shouting, singing, exercising) that increased the concentration of suspended respiratory droplets in the air space.
- **Inadequate ventilation or air handling** that allowed a build-up of suspended small respiratory droplets and particles.

Prevention of COVID-19 by airborne transmission

Existing interventions to prevent the spread of SARS-CoV-2 appear sufficient to address transmission both through close contact and under the special circumstances favorable to potential airborne transmission. Among these interventions, which include social distancing, use of masks in the community, hand hygiene, and surface cleaning and disinfection, **ventilation** and **avoidance of crowded indoor spaces** are especially relevant for enclosed spaces, where circumstances can increase the concentration of suspended small droplets and particles carrying infectious virus. At this time, there is no indication of a general community need to use special engineering controls, such as those required to protect against airborne transmission of infections, like measles or tuberculosis, in the healthcare setting.

SARS-CoV-2 is a new virus, and we are still learning about how it behaves.

There are several critical questions that need to be answered to refine guidance for prevention of COVID-19, including

- How effective are mitigation efforts to prevent SARS-CoV-2 spread, especially ventilation and masking?
- What proportion of SARS-CoV-2 infections are acquired through airborne transmission?
- What are the conditions that facilitate airborne transmission?
- What is the infectious dose for SARS-CoV-2 (how many virions are required for infection to occur)?
- Do inoculum size and route of inoculation affect risk of infection and disease severity?

REFERENCES

Alsved M, Matamis A, Bohlin R, Richter M, Bengtsson P-E, Fraenkel C-J, P. Medstrand P, Löndahl J. (2020) Exhaled respiratory particles during singing and talking, Aerosol Science and Technology, 2020. doi: 10.1080/02786826.2020.1812502 .

Bae S, Kim H, Jung TY, Lim JA, Jo DH, Kang GS, Jeong SH, Choi DK, Kim HJ, Cheon YH, Chun MK, Kim M, Choi S, Chun C, Shin SH, Kim HK, Park YJ, Park O, Kwon HJ. Epidemiological Characteristics of COVID-19 Outbreak at Fitness Centers in Cheonan, Korea. J Korean Med Sci. 2020 Aug 10;35(31):e288. doi: 10.3346/jkms.2020.35.e288. PMID: 32776726; PMCID: PMC7416003.

Brlek A, Vidovič Š, Vuzem S, Turk K, Simonović Z. Possible indirect transmission of COVID-19 at a squash court, Slovenia, March 2020: case report. Epidemiol Infect. 2020 Jun 19;148:e120. doi: 10.1017/S0950268820001326. PMID: 32600479; PMCID: PMC7327185.

Cai J, Sun W, Huang J, Gamber M, Wu J, He G. Indirect Virus Transmission in Cluster of COVID-19 Cases, Wenzhou, China, 2020. Emerg Infect Dis. 2020 Jun;26(6):1343-1345. doi: 10.3201/eid2606.200412. Epub 2020 Jun 17. PMID: 32163030; PMCID: PMC7258486.

Hamner L, Dubbel P, Capron I, Ross A, Jordan A, Lee J, Lynn J, Ball A, Narwal S, Russell S, Patrick D, Leibrand H. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice – Skagit County, Washington, March 2020. MMWR Morb Mortal Wkly Rep. 2020 May 15;69(19):606-610. doi: 10.15585/mmwr.mm6919e6. PMID: 32407303.

Infection Prevention and Control of Epidemic- and Pandemic-Prone Acute Respiratory Infections in Health Care. Geneva: World Health Organization; 2014. PMID: 24983124.

Jang S, Han SH, Rhee JY. Cluster of Coronavirus Disease Associated with Fitness Dance Classes, South Korea. Emerg Infect Dis. 2020 Aug;26(8):1917-1920. doi: 10.3201/eid2608.200633. Epub 2020 May 15. PMID: 32412896; PMCID: PMC7392463.

Li Y, Leung GM, Tang JW, Yang X, Chao CY, Lin JZ, Lu JW, Nielsen PV, Niu J, Qian H, Sleigh AC, Su HJ, Sundell J, Wong TW, Yuen PL. Role of ventilation in airborne transmission of infectious agents in the built environment – a multidisciplinary systematic review. Indoor Air. 2007 Feb;17(1):2-18. doi: 10.1111/j.1600-0668.2006.00445.x. PMID: 17257148.

Li Y, Qian H, Hang J, Chen X, Hong L, Liang P, Li J, Shenglan X, We J, Liu L, Kang M. Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant. medRxiv. doi.org/10.1101/2020.04.16.20067728. 2020.

Lu J, Gu J, Li K, Xu C, Su W, Lai Z, Zhou D, Yu C, Xu B, Yang Z. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. Emerg Infect Dis. 2020 Jul;26(7):1628-1631. doi: 10.3201/eid2607.200764. Epub 2020 Apr 2. PMID: 32240078; PMCID: PMC7323555.

Lu J, Yang Z. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. Emerg Infect Dis. 2020 Sep 11;26(11). doi: 10.3201/eid2611.203774. Epub ahead of print. PMID: 32917292.

Morawska L, Milton DK. It is Time to Address Airborne Transmission of COVID-19. Clin Infect Dis. 2020 Jul 6:ciaa939. doi: 10.1093/cid/ciaa939. Epub ahead of print. PMID: 32628269; PMCID: PMC7454469.

Oran DP, Topol EJ. Prevalence of Asymptomatic SARS-CoV-2 Infection : A Narrative Review. Ann Intern Med. 2020 Sep 1;173(5):362-367. doi: 10.7326/M20-3012. Epub 2020 Jun 3. PMID: 32491919; PMCID: PMC7281624.

Shen Y, Li C, Dong H, Wang Z, Martinez L, Sun Z, Handel A, Chen Z, Chen E, Ebell MH, Wang F, Yi B, Wang H, Wang X, Wang A, Chen B, Qi Y, Liang L, Li Y, Ling F, Chen J, Xu G. Community Outbreak Investigation of SARS-CoV-2 Transmission Among Bus Riders in Eastern China. JAMA Intern Med. 2020 Sep 1. doi: 10.1001/jamainternmed.2020.5225. Epub ahead of print. PMID: 32870239.

Tang S, Mao Y, Jones RM, Tan Q, Ji JS, Li N, Shen J, Lv Y, Pan L, Ding P, Wang X, Wang Y, MacIntyre CR, Shi X. Aerosol transmission of SARS-CoV-2? Evidence, prevention and control. Environ Int. 2020 Aug 7;144:106039. doi: 10.1016/j.envint.2020.106039. Epub ahead of print. PMID: 32822927; PMCID: PMC7413047.

World Health Organization. (2020). Transmission of SARS-CoV-2: implications for infection prevention precautions: scientific brief, 9 July 2020, World Health Organization. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

Yu IT, Li Y, Wong TW, Tam W, Chan AT, Lee JH, Leung DY, Ho T. Evidence of airborne transmission of the severe acute respiratory syndrome virus. N Engl J Med. 2004 Apr 22;350(17):1731-9. doi: 10.1056/NEJMoa032867. PMID: 15102999.

Last Updated Oct. 5, 2020